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The effects of sector reforms on the productivity of Greek banks: A step-by-step analysis of the pre-Euro era

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Abstract

The paper analyses the effects on the productivity of Greek commercial banks of sector regulatory reforms in the pre-Euro era, using the Global Malmquist Index. In a bootstrap Data Envelopment Analysis framework, we propose an alternative to smoothing that utilises the Pearson system random number generator, offering greater flexibility in the choice of the fitting distribution. In the context of a step-by-step approach, we demonstrate the contribution of deregulatory commercial freedoms to greater productivity and the negative effect of prudential controls. Our findings offer insights into the current state of the Greek banking sector, suggesting that the imposition of additional prudential controls may have a detrimental impact on the productivity of Greek banks, given the adverse business conditions.

Keywords: bank productivity, bank regulation; Global Malmquist Index, moments bootstrap DEA

JEL classification: C14, G21, G28

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1 Introduction

There is an ongoing debate about the effects of regulation and deregulation on the productivity of banking institutions, and this debate has become topical since the EU debt crisis and the creation of the Single Supervisory Mechanism (SSM). In the literature, the effects of deregulation, which is usually followed by reregulation, are evaluated on an overall basis, by comparing the productivity levels before and after the reforms. This paper uses a step-by-step approach to examine the effects on the productivity of Greek banks of the major regulatory shifts of the period from 1987 to 1999, during and after the reforms. We use a comprehensive dataset of Greek banks that hitherto has not been explored. Accounting for the significance in productivity change, we propose an alternative bootstrap data envelopment analysis (DEA) approach, which uses the Pearson system random number generator in lieu of kernel density estimators, offering greater flexibility in the choice of the fitting distribution.

Analysing the above is of great importance, as the reforms that occurred in the period of our study completely altered the structure of the Greek banking sector. This is mainly due to the fact that the Greek banking sector was heavily regulated until the late 1980s, and was characterised by a high concentration relative to other EU countries. The major reforms during the period 1987 to 1992 were aimed at the deregulation of the sector, providing Greek banks with commercial freedoms in order to make them more competitive in anticipation of the Single Market. However, prudential controls were imposed in 1993 to ensure the capital adequacy and quality of the supervised entities. The reforms, combined with the prospect of the Single Market, attracted more entrants into the sector, significantly reducing the concentration ratio. After 1997 and before the accession of Greece to the Economic Monetary Union (EMU) in 2001, Greek banks consolidated in order to reach the size required to compete at a European level; this occurred amidst the Athens Stock Exchange crisis, which started in 1999.

Despite the access to cheap funds that the EMU would offer to all banking institutions, the Greek sovereign debt crisis severely affected the Greek banking sector. Most of the Greek banks became technically insolvent by 2012 and had to undergo substantial recapitalisation processes to meet the requirements of the supervisory framework. The concentration ratio has reached high levels again, as some banks failed to survive the crisis, while others merged in order to meet capital requirements. Recently, Greek systemic banks were included in the SSM, which has substantial power over the operations of its supervised entities and can impose additional and stricter prudential controls. In the light of the above, we observe similarities in the state of the Greek banking sector between now and 1987: the sector is highly concentrated and highly scrutinised, while the business environment is not encouraging. Moreover, the prospect of additional controls being imposed may have negative implications for the productivity of Greek banking institutions. Therefore, it is essential to use the lessons from the major sector reforms of the past to comment on the potential effects of regulatory shifts on the productivity of Greek banks.

This paper addresses this question by examining the effects on the productivity of Greek commercial banks of sector reforms from 1987, when they were implemented, up to 1999. Unlike previous studies, which computed an average response to regulatory reforms (Gilbert and Wilson 1998; Isik and Hassan 2003), our study analyses the effects of each step of the deregulation and reregulation process on the productivity of Greek banks, and tests the hypothesis that the provision of commercial freedoms has improved the productivity of Greek banks whereas the imposition of prudential controls has had the opposite effect. Our study is methodologically related to that of Simar and Wilson (1998), while empirically it contributes to a vast branch of literature in banking regulation, including studies such as Humphrey and Pulley (1997), Gilbert and Wilson (1998), Christopoulos and Tsionas (2001), Isik and Hassan (2003), Brissimis et al. (2008), Delis et al. (2011), Chortareas et al. (2012) and Casu et al. (2015).

We measure productivity change using the Global Malmquist Index (GMI), which we estimate using DEA; this is a more flexible method than other parametric approaches, in that it is not necessary to specify a production function, and can be applied in multiple input–output models. We examine our research hypothesis empirically by introducing an application of bootstrap DEA on the GMI, namely the *moments bootstrap DEA*. The proposed approach uses a Pearson family random number generator to enrich the empirical distribution of DEA estimates, and is more flexible than kernel density estimation methods (also known as *smooth bootstrap* methods), which rely on the assumption of a pre-specified distribution (usually normal) and which, it is argued, introduce additional noise (Simar and Wilson 2002).

The empirical results lend support to our stated hypothesis. We find that improvement in productivity is associated with a relative reduction in banks' inputs, whereas deterioration in productivity is usually linked to a decline in securities and a fall in net loans, though to a smaller extent. The immediate years following the sector reforms saw a relative flattening of the productivity of Greek banks, leading eventually to higher levels that could be attributed to the positive economic environment of that period. This paper suggests that the proposed additional prudential controls, combined with the current pessimistic economic and business climate in Greece, may lead to a worsening of the productivity of Greek banks.

The rest of the paper is structured as follows. Section 2 succinctly reviews the relevant literature, section 3 introduces the moments bootstrap DEA and discusses its implementation, section 4 presents the data, section 5 analyses the empirical results, and section 6 concludes.

2 Background

Deregulation allows the redistribution of inputs allocated as a result of (or restrained by) supervision and compliance to more productive purposes, through the removal of certain restrictions and by providing commercial freedoms to banks. A better allocation of resources is expected to increase efficiency, while the benefits to society include reduced intermediation costs, higher quality and the provision of a wider range of products and services. However, deregulation, when used to increase banking sector competitiveness, can have an aggressive character that may not lead to efficiency improvements. The provision of commercial freedoms is usually followed by reregulation and the imposition of prudential controls (Benston 2000; Matthews and Thompson 2014) in order to limit the risks to which banks may be exposed as the result of moral hazard and the undertaking of risky activities.

More regulation tends to hinder total factor productivity growth (Crafts 2006), although in the long run structural reforms lead to productivity gains (Papageorgiou and Vourvachaki 2016). The effects of (de)regulation on banking efficiency and productivity depend on the purpose of the reforms, while other factors, such as the economic conditions, monetary policy, and the timing and process of implementing the reforms, should also be taken into account. (De)regulation may affect efficiency and productivity through a reconsideration of the input/output mix in the banking production process. Berger and Humphrey (1997) find that there is no consensus on the effects of (de)regulation on bank efficiency and productivity, and that the views of scholars depend on the approach followed as well as the specific characteristics of the cases examined.

Extensive US studies find negative effects on productivity during and after the deregulation of the 1980s (see Humphrey 1993; Humphrey and Pulley 1997; Wheelock and Wilson 1999). However, after a four-year period of continuous input reduction and adjustment of output prices, US banks recovered and improved their profitability, with this being driven by the improved business environment (Humphrey and Pulley 1997). Similarly, European studies document an increase in productivity after deregulation, commonly focusing on the period of the late 1980s to the early 1990s in anticipation of the Single Market (Altunbas et al. 1999, 2001; Brissimis et al. 2008; Chortareas et al. 2013; Casu et al. 2015). These studies find that EU banks exhibited gains in productivity, on average, after deregulation allowed them commercial freedoms. Gains in productivity appear to have been more significant towards the end of the reform process, for countries that had newly joined the EU (Brissimis et al. 2008). However, government interventions in private banks' policies and the monitoring of their practices had a negative effect on their efficiency, as opposed to capital quality regulations, which had a positive effect (Chortareas et al. 2012).

Studies on the effects of regulatory reforms on the performance of banks in Asian countries report mixed results. Positive effects are reported by Gilbert and Wilson (1998) for the deregulation of the Korean banking sector. Kumbhakar and Sarkar (2003) examine the case of Indian banks and find that productivity increased after the deregulation of the early 1990s; however, regulatory effects persisted in the post-deregulation period in the form of distortions in input prices (mainly due to over-employment). Chen et al. (2005) document a decline in the average levels of technical and allocative efficiency of Chinese banks after the (de)regulation of 1995,[1] but Matthews and Zhang (2010) found

[1] Their results also indicate a small decline in the average technical, allocative and cost efficiency after the first year of (de)regulation. Although the authors do not comment on this, it could be attributed to the fact that, in 1995, Chinese commercial banks were banned from participating in non-traditional banking activities such as insurance or securities trading.

no improvement in Chinese bank productivity after the deregulatory event of the World Trade Organisation (WTO) opening of the market to foreign competition.

The literature on Greek banking also reports mixed results, depending on the period examined and the approach followed. The majority of studies focus on the post-deregulation period, and specifically the period from 1993 to 1998. In particular, these studies find that productivity increases (except in the first year) and that large banks are less cost efficient than small ones (Christopoulos et al. 2002; Tsionas et al. 2003). However, there seems to be room for substantial improvement in cost efficiency for all banks (Christopoulos and Tsionas 2001). To our knowledge, the only study of Greek banking that covers the full period of deregulation (that is, from 1987 onwards) is that of Rezitis (2006), but he uses a dataset of only six banks over the period from 1982 to 1997.

The literature on the effects of bank (de)regulation, although vast, focuses only on the overall or average effects of (de)regulation; the effects of each step of the deregulation process are neglected, which is a gap in the literature that this paper tries to address. Moreover, it should be taken into account that it takes time for such effects to be manifested in bank efficiency. Delis et al. (2011), in their European study on regulation, and Orea (2002), who examined the mergers and acquisitions of Spanish savings banks, assume lagged effects of one year in their studies. This is also the case for Greece, where Siriopoulos and Tziogkidis (2010) find that significant destabilising events have a negative impact on banks' technical efficiency the year after the event, and that this is followed by a period of recovery which may last from two to four years. Apart from the fact that it takes time to implement regulations after the date they are announced, the presence of strong trade unions or labour laws (as in Greece) mean that the potential for cost reductions or the better allocation of resources are not necessarily exploited in the short run, and banks may instead experience a decline in efficiency. In summary, the two empirical gaps that we identify in the empirical literature are that no study follows a step-by-step approach to analyse the effects of (de)regulation, while we found no Greek banking studies that cover the full period of reforms.

3 Method

To compute the technical efficiency scores of the decision making units (DMUs) in our sample, we employ data envelopment analysis (DEA) under the assumption of constant returns to scale (CRS).[2] DEA is flexible in that it does not require the specification of a production function, and it has been

[2] The early literature provides evidence in support of CRS in the form of flat, U-shaped cost curves (Berger et al. 1993), while later studies turn their attention to unexploited economies of scale by small banks that provide arguments in support of variable returns to scale (VRS) (Berger and Mester 1997). However, Matthews and Thompson (2014) argue that studies of scale economies exist in mature banking markets that accommodate small banks alongside large multinational ones, and conclude that the potential for scale economies is left open in the literature. The choice of CRS in this paper is justified by the fact that CRS are associated with the minimisation of long run average costs and the exploitation of economies of scale, which we deem to be one of the desirable effects of deregulation. The CRS assumption is also consistent with a service industry. In contrast, the VRS assumption that may be appropriate for short periods is questionable in a dataset covering 13 years. Another reason for the choice of the CRS assumption is that the median scale efficiency is 0.989, suggesting that half of the DMUs in the sample are associated with a scale efficiency between 0.99 and 1.

widely applied in banking (see Afsharian and Ahn 2015; An et al. 2015; Pastor et al. 2006). Given that banks have more control over their inputs than they do over their outputs, it seems reasonable to utilise an input-oriented model in which inefficiencies are interpreted as the radial deviations of inputs from their efficient levels (Cook et al. 2014). Productivity change is then computed using Pastor and Lovell's (2005) Global Malmquist Index (GMI), which involves applying DEA on a global frontier and performing straightforward computations using the resulting global efficiency scores. Finally, the moments bootstrap DEA is used to test our research hypothesis on productivity change. This section first presents the proposed moments bootstrap DEA, and then we explain how this is implemented in the case of the Global Malmquist Index.

3.1 The moments bootstrap DEA

The moments bootstrap utilises the Pearson system random number generator to replace the relevant smoothing step in the conventional bootstrap DEA. The advantage of the moments bootstrap is that it is flexible, as it draws the best-fitting distribution from among a wide range of distributions, in contrast to smoothing, where a normal distribution kernel is usually fitted. The moments bootstrap is also computationally straightforward.

Our approach differs from the study of Simar and Wilson (1998) in that, instead of drawing from some smoothed counterpart of the empirical distribution, pseudo-efficiency scores are drawn directly from the underlying population. To do this, we first estimate the DEA technical efficiency scores for all n DMUs in the sample, using $j = 1,2, \ldots p$ inputs to produce $r = 1,2, \ldots q$ outputs. Let $\mathbf{x} = [x_{i,j}]$ and $\mathbf{y} = [y_{i,r}]$ be the $n \times p$ matrix of inputs and the $n \times q$ matrix of outputs, respectively. The CRS technical efficiency score for the k^{th} DMU, denoted as $\hat{\theta}_k$, for any k and for $i = 1,2, \ldots n$ is estimated as follows:

$$\hat{\theta}_k = \min\left\{\theta_k | \left(y_k \leq \sum_{i=1}^{n} \lambda_i y_{i,r}\,;\ \theta_k x_k \geq \sum_{i=1}^{n} \lambda_i x_{i,j}\,;\ \theta_k > 0; \lambda_i \geq 0\right)\right\} \tag{1}$$

where x_k and y_k are the observed inputs and outputs of the k^{th} DMU, respectively, $\theta_k \leq 1$ is an input expansion factor for the k^{th} unit chosen such that $\theta_k x_k$ lies on the efficient frontier, and λ_i are the weights of the envelopment model in equation (1) that are attached to each unit.

In the second step, we compute the first four moments of the empirical distribution, which are used to identify the Pearson type distribution from which pseudo-efficiency scores will be randomly drawn.[3] The Pearson system includes probability density functions that satisfy a differential equation that has the following form (Johnson et al. 1994):

$$\frac{1}{p}\frac{dp}{dx} = -\frac{x + a}{c_0 + c_1 x + c_2 x^2} \tag{2}$$

[3] Note that in the computation of the first four moments (sample mean, variance, skewness and kurtosis) the Pearson system uses the standard deviation.

The shape of the distribution depends on the parameters a, c_0, c_1 and c_2, while the roots of the equation:

$$c_0 + c_1 x + c_2 x^2 = 0 \tag{3}$$

define the solution in (2) and therefore the distribution type of the Pearson system.

The distribution types in the Pearson system include the normal distribution (Type 0), the beta distribution (Type I), the symmetric beta distribution (Type II), the gamma distribution (Type III), a non-standard density corresponding to no real roots in (3), the inverse gamma distribution (Type V), a family of distributions to which the F-distribution belongs (Type VI) and a family of distributions to which the t-distribution belongs (Type VII). The solutions for $a, c_0,\ c_1$ and c_2 satisfy the following system (Johnson et al. 1994):

$$\begin{aligned} c_0 &= (4\beta_2 - 3\beta_1)(10\beta_2 - 12\beta_1 - 18)^{-1} \\ c_1 &= \alpha = \sqrt{\beta_1}(\beta_2 + 3)(10\beta_2 - 12\beta_1 - 18)^{-1} \\ c_2 &= (2\beta_2 - 3\beta_1 - 6)(10\beta_2 - 12\beta_1 - 18)^{-1} \\ &\beta_1 = (skewness)^2 \text{ and } \beta_2 = kurtosis \end{aligned} \tag{4}$$

Depending on the combination of values of these parameters and the value taken by $\kappa = \frac{1}{4} c_1^2 (c_0 c_2)^{-1}$, a unique distribution is identified from the Pearson system.[4] To give an example, suppose that $c_1 = c_2 = 0$; the solution to (2) would then be:

$$p(x) = K \exp\left[-\frac{(x+a)^2}{2c_0}\right] \tag{5}$$

where K is the integrating constant and has to be $K = \sqrt{2\pi c_0}$ in order to satisfy $\int_{-\infty}^{\infty} p(x)dx = 1$. Hence $p(x) = \sqrt{2\pi c_0} \exp\left[-\frac{(x+a)^2}{2c_0}\right]$ is the resulting probability distribution with expected value a and standard deviation c_0. This is a Type 0 distribution in the Pearson system and corresponds to the Normal distribution.

Next, in each of the $b = 1,2, \dots B$ bootstrap replications, n pseudo-efficiency scores $(\theta_i^*, i = 1,2 \dots n)$ are randomly drawn from the identified distribution, truncated between 0 and 1.[5] A bootstrap pseudo-sample $(\mathbf{x}^*, \mathbf{y})_b$ can be generated with inputs $\mathbf{x}^* = \left[x_{i,j}^*\right]$ and outputs $\mathbf{y} = \left[y_{i,r}\right]$, where for the pseudo-input vector of the k^{th} DMU we have:

$$x_k^* = \frac{\hat{\theta}_k x_k}{\theta_k^*} \tag{6}$$

[4] The sufficient criteria for the characterisation of a distribution type are: Type 0: $c_1 = 0, \beta_2 = 3$; Type I: $\kappa < 0$; Type II: $\beta_1 = 0, \beta_2 < 3$; Type III: $2\beta_2 - 3\beta_1 - 6 = 0$; Type IV: $0 < \kappa < 1$; Type V: $\kappa = 1$; Type VI: $\kappa > 1$; Type VII: $\beta_1 = 0, \beta_2 > 3$.

[5] Although this could be considered as a limitation of the proposed approach, simulations show that the practice of truncating the distribution has a negligible effect on the results, especially as the sample size increases. In particular, we conducted separate Monte Carlo simulations and computed the median absolute differences (MADs) between the moments of the truncated "pseudo-populations" and the moments that would result without truncation. The resulting MADs are too small to affect the position or shape of the distribution, while for samples larger than 100 units the differences become negligible. The results of these tests are available upon request.

Finally, the bootstrapped technical efficiency scores $\left(\hat{\theta}_k^*\right)$ are computed by applying DEA on the pseudo-sample $(\mathbf{x}^*, \mathbf{y})_b$. The bootstrapped efficiency score for the k^{th} unit and for each of the $b = 1,2, \dots B$ bootstrap replications is:

$$\hat{\theta}_{k(b)}^* = min \left\{\theta_k | \left(y_k \leq \sum_{i=1}^{n} \lambda_i y_{i,r} \, ; \, \theta_k x_k \geq \sum_{i=1}^{n} \lambda_i x_{i,j}^* \, ; \, \theta_k > 0; \, \lambda_i \geq 0 \right)\right\} \tag{7}$$

The resulting distribution of bootstrapped efficiency scores $\hat{\theta}_k^* = \left\{\hat{\theta}_{k(b)}^*, \quad b = 1,2, \dots B\right\}$ is inwards biased, and Simar and Wilson (1998) suggest correcting it twice for bootstrap bias, so that it is centred on the (unobservable) population efficiency score θ_k. This is based on the assumption that the model bias $\left(\hat{\theta}_k - \theta_k\right)$ under the data generating process $(\mathcal{P})$ is well-approximated by the bootstrap bias $\left(\hat{\theta}_k^* - \hat{\theta}_k\right)$ under the data generating process $\left(\hat{\mathcal{P}}\right)$:

$$\left(\hat{\theta}_k^* - \hat{\theta}_k\right) | \hat{\mathcal{P}} \sim \left(\hat{\theta}_k - \theta_k\right) | \mathcal{P} \tag{8}$$

We denote the bias-corrected distribution of the efficiency scores as $\tilde{\theta}_k^* = \left\{\tilde{\theta}_{k(b)}^*, b = 1 \dots B\right\}$. In line with Simar and Wilson (1998), a reasonable estimate of the population efficiency score of the k^{th} DMU is the expected value of $\tilde{\theta}_k^*$:

$$E\left(\tilde{\theta}_k^*\right) = E\left(\hat{\theta}_k^*\right) - 2\widehat{bias}_k = E\left(\hat{\theta}_k^*\right) - 2\left[E\left(\hat{\theta}_k^*\right) - \hat{\theta}_k\right] = 2\hat{\theta}_k - \frac{1}{B}\sum_{b=1}^{\mathrm{B}} \hat{\theta}_{k(b)}^* \tag{9}$$

Define the $(\alpha/2)^{\text{th}}$ and $(1 - a/2)^{\text{th}}$ percentiles of $\tilde{\theta}_k^*$ as $\tilde{\theta}_k^{*,(a/2)}$ and $\tilde{\theta}_k^{*,(1-a/2)}$, respectively. The $(1 - a)\%$ confidence interval for θ_k is then $\left(\tilde{\theta}_k^{*,(a/2)} \, , \, \tilde{\theta}_k^{*,(1-a/2)}\right)$.

3.2 *The Global Malmquist Index*

Productivity change is estimated using Pastor and Lovell's (2005) Global Malmquist Index (GMI). All DMUs are assessed under a common global frontier that comprises DMUs across all time periods. The GMI is then calculated as the ratio of the resulting global efficiency scores between adjacent periods. Define the contemporaneous technology (or feasible set) in period t as:

$$\Psi^t = \left\{(\mathbf{x}^t, \mathbf{y}^t) \in \mathbb{R}_+^{p+q} | \mathbf{x}^t \text{ can produce } \mathbf{y}^t\right\}, \quad t = 1,2, \dots T \tag{10}$$

where $\mathbf{x}^t$ and $\mathbf{y}^t$ denote the sets of inputs and outputs used by all DMUs in period t.

The global technology is defined as the convex hull of the contemporaneous technologies (Pastor and Lovell 2005):

$$\Psi^G = \text{conv}\left\{\Psi^1 \bigcup \dots \bigcup \Psi^T\right\} \tag{11}$$

Suppose that the k^{th} DMU uses the input vector x_k^t to produce the output vector y_k^t in period t, and that the global frontier comprises N observations.[6] Define the technical global efficiency score of the

[6] We use $1,2, \dots N$ to denote all DMUs included in the unbalanced panel of DMUs that comprise the global reference set. We use the time subscripts for the DMU under evaluation to ease the exposition, as we find this presentation more straightforward when it comes to the computation of productivity change over time.

k^{th} DMU for period t as $\theta_k^G(x_k^t, y_k^t)$ and for period $t+1$ as $\theta_k^G(x_k^{t+1}, y_k^{t+1})$. The GMI for the k^{th} DMU between periods t and $t+1$ is defined as[7]:

$$M^G(x_k^t, y_k^t, x_k^{t+1}, y_k^{t+1}) = \frac{\theta_k^G(x_k^t, y_k^t)}{\theta_k^G(x_k^{t+1}, y_k^{t+1})} \tag{12}$$

If $M^G < 1$ then the productivity of the k^{th} DMU has increased between periods t and $t+1$ (under input orientation), if $M^G > 1$ the opposite is true, whereas $M^G = 1$ indicates no change in productivity.

We use DEA to estimate the global technical efficiency scores in equation (12) (for the period t and similarly for the period $t+1$):

$$\hat{\theta}_k^G(x_k^t, y_k^t) = \min\left\{\theta_k^G \mid \sum_{i=1}^{N} \lambda_i y_{i,r}\,;\ \theta_k^G x_k^t \geq \sum_{i=1}^{N} \lambda_i x_{i,j}\,;\ \theta_k^G > 0; \lambda_i \geq 0\right\} \tag{13}$$

where x_i, y_i and λ_i are the vectors of inputs, outputs and envelopment weights, respectively, of the i^{th} DMU, for $i = 1,2, \dots N$. The estimates $\hat{\theta}_k^G(x_k^t, y_k^t)$ and $\hat{\theta}_k^G(x_k^{t+1}, y_k^{t+1})$ are used to compute the value of M^G, denoted as $\widehat{M}^G(x_k^t, y_k^t, x_k^{t+1}, y_k^{t+1})$ using the formulation of equation (12).

3.3 *Testing the research hypothesis*

We test for productivity changes and their direction with the following two-step process:

$$\begin{aligned} &R_0: M^G(x_k^t, y_k^t, x_k^{t+1}, y_k^{t+1}) = 1 \\ &R_1: M^G(x_k^t, y_k^t, x_k^{t+1}, y_k^{t+1}) > 1, \qquad \text{or} \qquad R_2: M^G(x_k^t, y_k^t, x_k^{t+1}, y_k^{t+1}) < 1 \end{aligned} \tag{14}$$

We use the moments bootstrap DEA, with $B = 2{,}000$ bootstrap replications for the k^{th} DMU at times t and $t+1$ to estimate $\hat{\theta}_k^G(x_k^t, y_k^t)_b^*$ and $\hat{\theta}_k^G(x_k^{t+1}, y_k^{t+1})_b^*$. Assuming that $(\hat{\theta}_k^{G,*} - \hat{\theta}_k^G) | \hat{\Psi}^G \sim (\hat{\theta}_k^G - \theta_k^G) | \Psi^G$, we can obtain a bias-corrected estimate $E(\tilde{\theta}_k^{G,*})$ of the population global efficiency score of the k^{th} DMU (θ_k^G) as follows:

$$E(\tilde{\theta}_k^{G,*}) = E(\hat{\theta}_k^{G,*}) - 2\widehat{bias}_k = 2\hat{\theta}_k^G - \frac{1}{B}\sum_{b=1}^{\mathrm{B}} \hat{\theta}_{kb}^{G,*} \tag{15}$$

We use the bias-corrected distributions $\tilde{\theta}_k^G(x_k^t, y_k^t)_b^*$ and $\tilde{\theta}_k^G(x_k^{t+1}, y_k^{t+1})_b^*$ to obtain bootstrap values of the GMI ratios:

$$\widetilde{M}^G(x_k^t, y_k^t, x_k^{t+1}, y_k^{t+1})_b^* = \frac{\tilde{\theta}_k^G(x_k^t, y_k^t)_b^*}{\tilde{\theta}_k^G(x_k^{t+1}, y_k^{t+1})_b^*}, \qquad b = 1,2, \dots B \tag{16}$$

The $(\alpha/2)^{th}$ and $(1 - a/2)^{th}$ percentiles of $\widetilde{M}^G(x_k^t, y_k^t, x_k^{t+1}, y_k^{t+1})_b^*$ are used for the research hypothesis; if $1 \notin \left(\widetilde{M}_b^{G,*,(a/2)}, \widetilde{M}_b^{G,*,(1-a/2)}\right)$, we can accept the alternative that productivity has

[7] We should note that, given that GMI is circular in the sense that $M^G(x_k^t, y_k^t, x_k^{t+\kappa}, y_k^{t+k}) = M^G(x_k^t, y_k^t, x_k^{t+1}, y_k^{t+1}) \cdot \dots M^G(x_k^{t+k-1}, y_k^{t+k-1}, x_k^{t+k}, y_k^{t+k})$, etc., the same test can be applied between any two periods t and $t+\kappa$.

changed from t to $t+1$. Moreover, the following p-values, denoted as $plow$ and $phigh$, can be used to test (14):

$$plow = \frac{\#\left(\widetilde{M}_b^{G,*} < 1\right)}{B} \quad \text{and} \quad phigh = \frac{\#\left(\widetilde{M}_b^{G,*} > 1\right)}{B}, \quad b = 1,2,\dots B \tag{17}$$

If there is evidence of productivity change (i.e., R_0 is not confirmed), then for $plow < a$ we accept the alternative $R_1: M^G\left(x_k^t, y_k^t, x_k^{t+1}, y_k^{t+1}\right) > 1$, which indicates a decline in productivity, and for $phigh < a$ we accept the alternative $R_1: M^G\left(x_k^t, y_k^t, x_k^{t+1}, y_k^{t+1}\right) < 1$, which indicates an increase in productivity.

4 Data

The dataset covers the period from 1987 to 1999, a period that is of particular significance for Greek banking. The period started with a five-year long process of deregulation in anticipation of the Single Market in 1993; this was followed by reregulation with the implementation of Basel I. The sample ends immediately after the launch of the EMU, which coincided with a bull run on the Athens Stock Exchange and a subsequent bursting of the bubble. Moreover, after 1999 the structure and conduct of the Greek banking sector changed to a large extent, with the effects from the (de)regulation having stabilised.

The process of (de)regulation includes a long list of banking reforms, which were brought in amid a period of intense efforts by the government to enhance the macroeconomic outlook for Greece in anticipation of the Single Market. The Single European Act provided the impetus for the Greek banking sector to modernise and become more competitive by 1993. Over this period, the deregulation process involved the liberalisation of interest rates, the removal of minimum reserve requirements, the abolition of compulsory purchases of governmental promissory notes and bonds, and the abolition of the compulsory financing of public companies and SMEs by commercial banks, as well as the removal of restrictions on capital mobility among EU Member states.

We obtained our dataset on Greek commercial banks from Bankscope and from archived and published financial statements of banks that we used to verify Bankscope and to add missing entries. The archived financial statements were obtained from the library of the Bank of Greece, the libraries of individual banks, which maintain historical archives, and from the finance divisions of the appropriate financial institutions when necessary. All values have been converted into Euros (using a fixed rate for EUR/DRC for ease of exposition) and adjusted for 1995 constant prices using the GDP deflator. Table 1 presents the list of commercial banks in the dataset. In each year, we include an artificial DMU, which we name the *Average Bank*, in order to capture the average behaviour of the Greek banking sector. The inputs and outputs for the *Average Bank* for a particular year are the average values of the inputs and outputs of all DMUs during that year. By definition, the artificial DMUs cannot be members of the efficient frontier, which comprises DMUs with high values in at least one of their input–output ratios.

Hence, the efficiency scores of these artificial DMUs are always less than 1, and their inclusion does not affect the shape or position of the frontier and therefore does not affect the efficiency scores of other banks.[8]

[Insert Table 1 here]

To measure bank efficiency, we use the intermediation approach, which deems banks to be financial intermediaries that transform their resources (productive capital, labour and deposit liabilities) into banking outputs (related to earning assets). For all the Greek commercial banks, we draw on fixed assets, personnel expenses and customer deposits as inputs, and net loans (loans minus provisions for bad debts) and other securities as outputs.[9] We should note that we have excluded from our analysis interbank activity (deposits and loans to other financial institutions), as we want to focus on the customer orientation of banks. Moreover, we have not included off balance sheet items because of data unavailability and because these items have only become more important in recent years. Finally, lack of data means that we are only able to compute technical efficiency and not cost efficiency, which would assess the effects of deregulation on the cost structures of financial institutions (Berger and Humphrey 1997). However, since we are using monetary values in an input-oriented model, we have incorporated the concept of cost minimisation in our analysis to some extent. Figure 1 illustrates the input–output relationships and the global efficiency scores in the Greek banking sector. Greek banks are technologically homogenous across all years of study, in that the input/output relationships are gathered in one cluster without any outliers.

[Insert Figure 1 here]

5 Empirical results

This section discusses our results on how the sector reforms affected the productivity of Greek banks. Our findings are summarised in Table 2 in conjunction with Figures 2 and 3, which focus on the *Average Bank*.[10] Table 2 presents the results of our research hypothesis for the *Average Bank,* and in addition provides an aggregated overview of the results for all banks in the sample. Figure 2 demonstrates the (log) input–output scatterplots for all banks and maps the input–output activities for the *Average Bank,* over time. Finally, Figure 3 presents the trajectory of the respective input–output combinations over time, along with an indication of the banks' global bias-corrected efficiency scores in each year.[11]

[Insert Table 2, Figure 2 and Figure 3 here]

[8] We also include a second artificial bank, acting as a representative large bank, using the weighted averages (weighted each year by total assets) of the variables of interest, to examine the extent to which the market is driven by large banks. The qualitative results do not change and we therefore discuss the results for the *Average Bank* for concision. Hence, the sample comprises 216 DMUs, of which 26 correspond to the aforementioned artificial observations.

[9] Bankscope defines other securities as the sum of investments of banks to associates through equity and other securities, which in turn includes bonds, equity derivatives and any other type of security.

[10] The same information for each bank can be found in the supplementary file, and we use this in our discussion.

[11] As a robustness check, we have applied the same methodology but using Simar and Wilson's (1998) bootstrap DEA and under two different smoothing methods: least squares cross-validation and Sheather and Jones' (1991) plug-in estimator. The position and width of the confidence intervals changes slightly, which relates to differences in the performance in the relevant simulations conducted by the authors. The results are available from the authors upon request.

The period of reforms spans the years 1987 to 1994. Comparing the global efficiency estimates for the starting year 1987 and the ending year 1994 of the (de)regulation period, we find mixed results across the banks for the effect of (de)regulation on productivity. We observe that the global bias-corrected efficiency scores are higher in 1994 than in 1987 for six banks, while the opposite is true for six other banks. However, this comparison of productivity levels between the start and the end of the period cannot capture the dynamic perspective of the regulatory reforms that arises from their multi-stage nature, as shown in the present study. Therefore, we consider each step of the (de)regulation process and of the relevant policy interventions.

The commercial freedoms given to Greek banks were limited during the first period of the reforms (1987 to 1988); in fact, only a few additional controls were imposed. As a result of the sector reforms that were announced, banks also had to reconsider their management. Hence, it is not likely that an increase in productivity would be observed during this period. Indeed, we find from Table 2 that the GMI for the *Average Bank* declines marginally, though insignificantly. Our results indicate that the decline was mainly driven by the substantial decrease in productivity of Cretabank, a large bank, and the decrease in productivity of National Bank, the largest bank in Greece. A common observation for that period, derived from Figure 3, is that both fixed assets and personnel expenses increased substantially. One possible explanation is that banks believed that they should expand their networks to exploit the forthcoming commercial freedoms, which is translated into a decline in productivity under the intermediation approach.

The initial deterioration in productivity was followed by an upturn during the periods 1988 to 1989 and 1989 to 1990 (as reported in Table 2), which we attribute to the commercial freedoms given to banks. These freedoms included, among others, the removal of interest rate ceilings, the freedom to set loan rates across certain industries, and the removal of selective credit controls. The increase in productivity from 1988 to 1989 was mainly driven by large banks, whereas from 1989 to 1990 all banks, with the exception of two, exhibited a significant increase in GMI. The main pattern associated with the increase in productivity was the reduction in fixed assets and personnel expenses, whereas loans seem to increase during 1988-1989 for most banks. This suggests that banks exploited the additional flexibility by reconsidering their input–output processes in a more productive way. However, the momentum of productivity growth was interrupted during 1990 to 1991, because of a leap in inflation, as shown in Table 2. We observe a substantial reduction in the value of securities (as shown in Figure 3), which is the main reason for the decrease in productivity.

The positive effects of deregulation resume during the next two periods, 1991-1992 and 1992-1993. The moderation efforts were successful, as inflation declined while real GDP growth accelerated. At the same time, the complete removal of the obligation of Greek banks to keep 40% of their deposits in Greek government promissory notes or other public enterprises meant that banks could use their inputs more productively. By the end of 1992 the deregulation process was almost complete, with the last few commercial freedoms being given to banks. Both the sector and individual banks experienced significant increases in productivity. From the analysis of the trajectories, we find that the enhanced productivity was associated with a relative decrease of all inputs relative to loans (shown in Figure 3). Most large banks exhibited an increase in securities (but this was not true for the smaller banks).

The deregulation wave was followed in 1993 by reregulation. The imposition of prudential controls after the introduction of the Basel rules on capital definition and liquidity, along with the introduction of financial accounting standards, suggested that banks would need to use more inputs and produce their outputs under stricter supervision. Since Basel I focused mainly on credit risk and the risk-weighting of assets for regulatory purposes, we would expect that banks would have reconsidered their securities portfolios. In fact, during the period 1993-1994, we observe a decrease in securities along with a small increase in personnel expenses that, to some extent, was required to support the higher resourcing requirements for compliance, and this led to a significant decrease in productivity for most banks, a pattern in line with that found by Tsionas et al. (2003).

The reforms of the (de)regulation period significantly affected the operations and management of Greek banks. During the next three periods, no other significant events were observed, allowing Greek banks to adjust fully to the new environment. The productivity of the Greek banking sector increased from 1994 to 1997, and the increase can be broken down into a small decline in productivity over the first two years, followed by a substantial increase, coinciding with a substantial improvement in the macroeconomic environment. Comparing the bias-corrected global efficiency scores between 1994 and 1997 (as presented in Figure 3), we observe that the majority of banks improved their performance; there were only a few exceptions, and these banks later became acquisition targets (Agricultural Bank, Attica Bank, Bank of Central Greece, Emporiki Bank and Ionian and Popular Bank). The prevailing behaviour in the banks' input–output trajectories is a relative increase in loans compared to inputs. Indeed, during that time, interest rates gradually declined and credit started to expand.

During the last two periods, the Greek banking sector underwent a period of significant change, with a merger and acquisition wave being followed by a bull stock market during the last quarter of 1999. Hence, it would be difficult to infer whether, and to what extent, the changes in banks' productivity are related to (de)regulation. However, it can be argued that the reforms contributed to preparing the ground for these changes in the sector. Looking at the results for the *Average Bank* in the period 1997-1999, we can deduce that banks experienced an increase in both inputs and outputs, which can be attributed to the decreasing interest rates and the possibilities opening up in anticipation of joining the Economic Monetary Union in the near future.

Summarising our analysis, the Greek banking sector follows the theoretical pattern that bank productivity increases after deregulation and tends to decrease after the imposition of controls (Matthews and Thompson 2014). In the post-reforms period, Greek banks reached higher levels of productivity, on average, supported by the good market conditions, in line with the study of Humphrey and Pulley (1997) for the US deregulation of the early 1980s. The regulatory reforms allowed the modernisation of Greek banks, which went through significant changes of ownership during 1997 to 1999, leading to substantial swings in productivity.

Our findings offer some insights into the current state of the Greek banking system. The imposition of additional prudential controls on Greek banks may have a negative impact on the productivity of the unstable Greek banking sector. These effects may be amplified by the regulatory capital (Tier I) requirements, which are affected by the credit rating agencies' quality assessment of government and corporate securities. Greek banks continue to hold a significant amount of Greek government securities, the ratings of which are affected by the deteriorating situation of the Greek economy. This has direct implications for the banks' Tier I capital: the negative prospects for the Greek economy may entail additional capital and liquidity requirements for Greek banks, which will have to turn to their productive assets or to deleveraging in order to meet the new demands.

6 Conclusion

The creation of the Single Supervisory Mechanism for a unified European banking supervision system has raised questions regarding its impact on bank efficiency and productivity. Greek banks are on the margins with respect to meeting their capital requirements, and are teetering on the boundary of insolvency. The imposition of regulations might severely affect their performance and their likelihood of survival. This paper uses the lessons of the past to draw inferences regarding the potential effects of the SSM on the productivity of Greek banks in the present.

We examine hypothesis related to the direction of the productivity change at every step of the (de)regulation process from 1987 to 1994, while we also consider the period up to 1999 to observe the Greek banks' behaviour in the aftermath of the sector reforms. We propose a bootstrap DEA approach that replaces smoothing with a Pearson random number generator, and we measure significance in productivity changes by applying the bootstrap in the context of the GMI. This paper contributes empirically by considering the effects of sector reforms on a *step-by-step* basis and by using data for all Greek banks during the period of the reforms. Our findings confirm that deregulation has a positive effect on the productivity of banks, whereas the imposition of prudential controls and the adoption of contractionary policies has a negative one. The analysis of banks' input–output trajectories suggests that the sector reforms gave incentives to the banks to reconsider their portfolios and their asset and liability structures. Regarding the post-reform period, we observe an expansion of the banks' activities and an overall increase in productivity for the following four years, supported by the improved business environment in Greece.

Finally, we draw insights from the period of the study to discuss implications for the current state of the Greek banking sector. The potentially stricter supervision and capital requirements under the SSM, combined with the weak business environment and the increase in non-performing loans, could lead to a severe deterioration of the productivity of Greek banks in the short run. This paper suggests that the regulatory authorities should ensure that the imposition of additional or stricter controls does not come at extra cost, especially for banks in distress, to allow for a smoother transition towards European Central Bank supervision.

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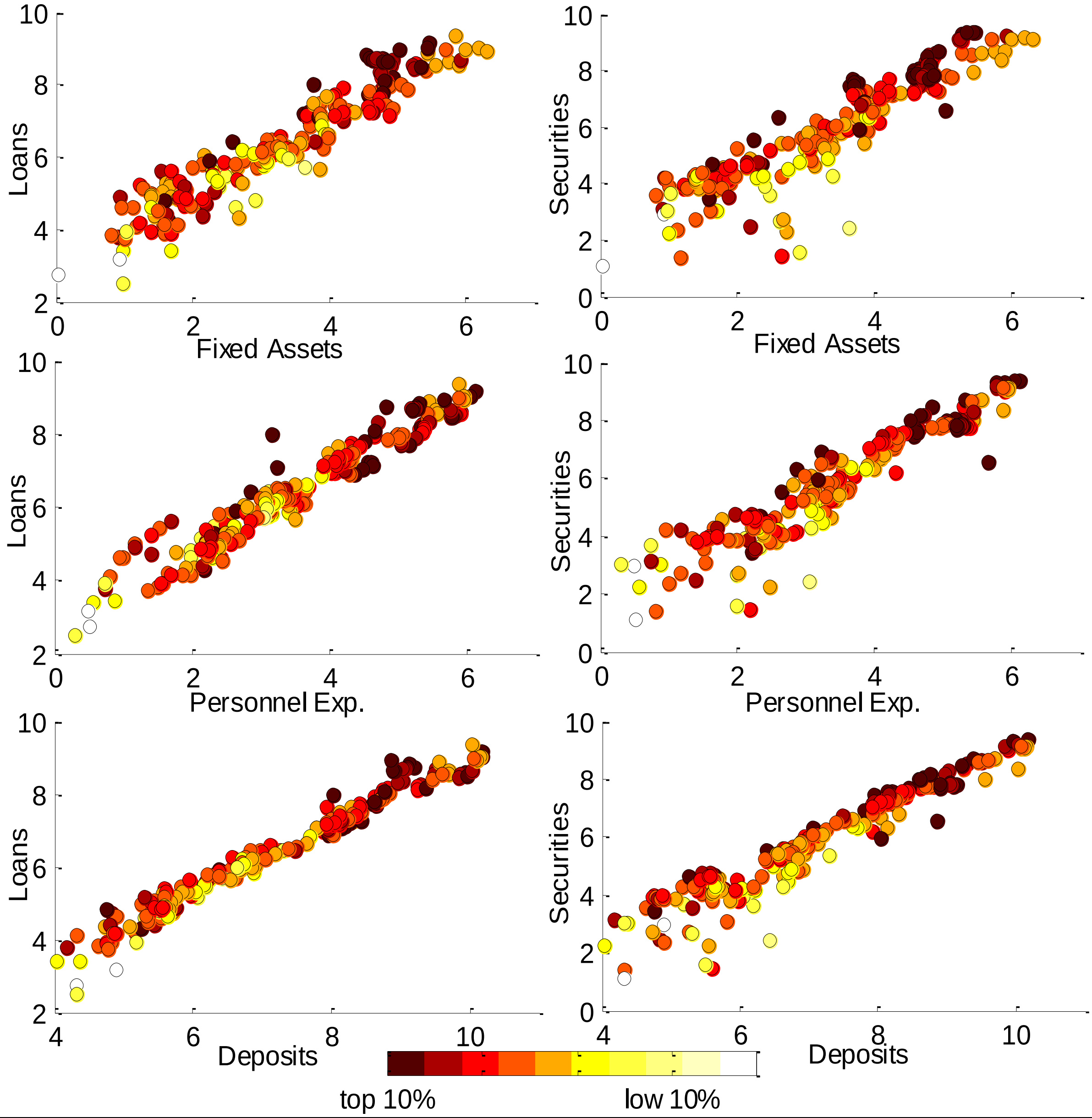
FIGURES AND TABLES

Table 1 List of Greek banks

	1987	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*Total*
Agricultural Bank	**NO**	**NO**	**NO**	**NO**	**NO**	YES	YES	YES	YES	YES	YES	YES	YES	**8**
Alpha Bank	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	**13**
Bank of Athens	N/A	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES			**10**
Attica Bank	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	**13**
Bank of Central Greece	YES	N/A	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES		**11**
Bank of Crete – Cretabank	YES	N/A	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES		**11**
Egnatia Bank							YES	YES	YES	YES	YES	YES	YES	**7**
Emporiki Bank	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	**13**
Ergobank	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	**13**
Eurobank Ergasias											YES	YES	YES	**3**
General Bank	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	**13**
Interbank									YES	YES				**2**
Ionian and Popular Bank	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES		**12**
Laiki Bank (Hellas)							YES	YES	YES	YES	YES	YES	YES	**7**
Macedonia-Thrace Bank	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	**13**
National Bank of Greece	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	**13**
Piraeus Bank	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	**13**
T Bank							YES	YES	YES	YES	YES	YES	YES	**7**
Xiosbank					YES	YES	YES	YES	YES	YES	YES	YES		**8**
Total	**11**	**10**	**12**	**12**	**13**	**14**	**17**	**17**	**18**	**18**	**18**	**17**	**13**	**190**

Note: In each year, “YES” denotes that the bank was included in the sample, “N/A” indicates that there were no available data, “NO” indicates that the bank was excluded from the sample, while blank spaces indicate no banking operations. We excluded the operations of the Agricultural Bank of Greece up to 1991 as it was formerly a not-for-profit organisation with a different business model from the commercial banking model. We also excluded from the sample three commercial banks operating in Greece during the period of study as they exhibited heterogeneity in their operations compared to the other banks; these were the Marfin Bank (a former investment bank), the Dorian Bank (which focuses on maritime finance and later became an investment bank) and the Cyprus Bank (the Greek branches of a Cypriot parent company).

Fig.1 Inputs/outputs and efficiency distribution



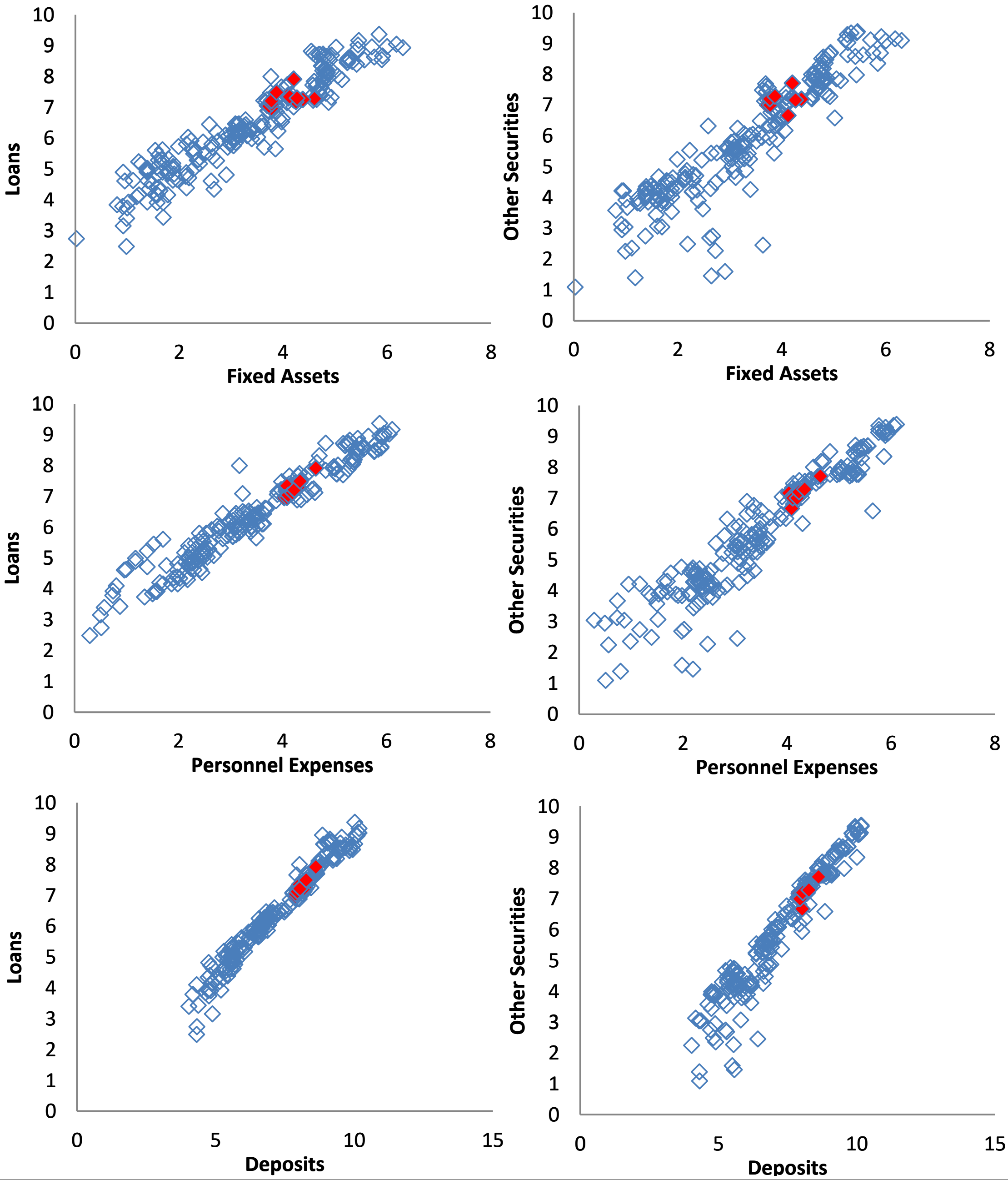
Note: The horizontal axes in each row correspond to the three inputs used and the vertical axes in each column correspond to the two outputs used. The values are expressed in natural logarithms, and therefore any movement along the plot is to be interpreted as a percentage change. Finally, the colour mapping corresponds to the efficiency scores observed in the sample; the higher the global efficiency score of a DMU, the darker the dot.

Table 2 Productivity change results

								Banks		
	GMI	**Ratio**	**Direction**	*CI 2.5%*	*CI 97.5%*	*plow*	*phigh*	*Up*	*Down*	*Sign.*
1987-1988	1.042	1.015	↓	0.945	1.090	0.361	0.640	6	4	6
1988-1989	1.000	0.991	↑	0.965	1.023	0.721	0.279	4	6	8
1989-1990	0.967	0.973*	↑	0.955	0.992	0.998	0.002	10	2	10
1990-1991	1.053	1.051	↓	0.992	1.116	0.048	0.952	4	8	8
1991-1992	0.902	0.886*	↑	0.841	0.932	1.000	0.000	7	6	9
1992-1993	0.893	0.926*	↑	0.881	0.974	0.998	0.002	8	6	9
1993-1994	1.062	1.044*	↓	1.015	1.078	0.000	1.000	4	13	14
1994-1995	1.016	1.017	↓	0.987	1.047	0.145	0.855	10	7	10
1995-1996	1.028	1.025*	↓	1.010	1.049	0.001	1.000	9	9	16
1996-1997	0.928	0.938**	↑	0.909	0.963	1.000	0.000	14	3	12
1997-1998	1.078	1.122**	↓	1.055	1.197	0.000	1.000	3	14	6
1998-1999	0.921	0.927**	↑	0.913	0.934	1.000	0.000	8	5	8

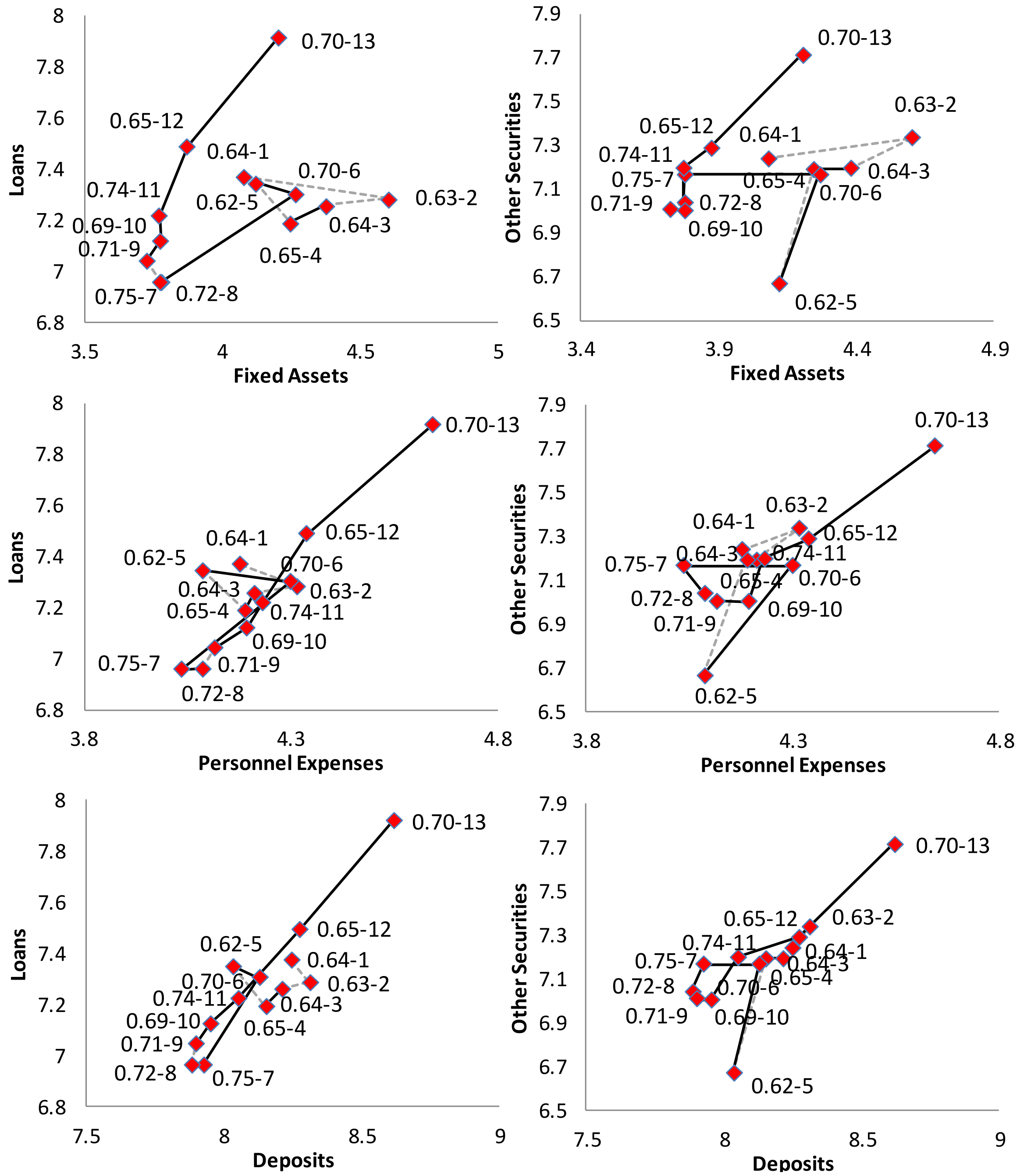
Note: This table presents, in columns 2 to 8, the results for the research hypothesis for the Average Bank, and it summarises these results for the other banks in the last three columns. The GMI is presented in column 2. Column 3 calculates the ratio of $E\left(\tilde{\theta}_k^{G,*}\right)$ between two adjacent time periods t and $t+1$, which serves as an indication of the direction of productivity change and is interpreted as the GMI. Also, one can inspect the changes in $E\left(\tilde{\theta}_k^{G,*}\right)$ between any two-time periods from Figure 3. A star (*) in the 3rd column indicates that the increase or decrease in productivity was significant at the 0.05 level of significance. The 4th column indicates the direction of productivity change according to column 3. The 5th and 6th columns report the 2.5th and 97.5th percentiles, which are used to test R_o, while the next two columns report the *p*-values (*plow* and *phigh*), which are used to test R_1. The last three columns of the table report the number of banks that exhibited an improvement (Up) or a decline (Down) in productivity, as well as how many of those movements were significant (Sign.). The analytical results for each bank can be found in the supplementary file.

Fig.2 Position of the Average Bank in the input–output space



Note: The scatterplots in this figure show the position of the input-output combinations of the *Average Bank* relative to the other banks. The axes are expressed in natural logarithms. The scatterplots for the individual banks can be found in the supplementary file.

Fig.3 Average Bank trajectory



Note: The input–output scatterplots in this figure show the trajectory that the *Average Bank* followed through time. Each dot has two numbers attached to it. The first number corresponds to the bias-corrected estimate of the global technical efficiency score, whereas the second number indicates the year, with 1 corresponding to 1987 and 13 to 1999. Solid lines indicate that the productivity change was significant at the 95% level of confidence whereas dashed lines indicate the opposite. The axes are expressed in natural logarithms. The trajectories for the individual banks can be found in the supplementary file.